

A NEW destructive insect is recorded from America; *Celonias*, a beetle which, according to the *American Naturalist*, was harmless, feeding on the sap of freshly cut maple-trees, has within two or three years become very abundant and destructive in different parts of New England. During the past summer it collected in great numbers on green-corn, "eating the kernels and partly destroying a field in Middleboro, Mass."

FAVOURABLE reports reach us as to the thriving condition of the Botanical Gardens, Peradeniya, Ceylon, under the direction of Dr. Trimen, who recently succeeded Dr. Thwaites. In the experimental nurseries, our contemporary the *Colonies* says, good work was being done. Every effort was being made to extend the cultivation of *Cinchona*, the export of which for the season, up to the date of latest advices, had been 1,135,236 lb. In the district of Kotmale report represented the india-rubber tree as flourishing, and the export of its valuable juice from the colony may, it is hoped, be eventually looked upon for supplementing the falling off in export of this valuable article from the forests where it is indigenous.

THE *Colonies and India* draws attention to the riches of the New Zealand forests in their indigenous timbers. Though the woods of New Zealand, like those of Australia, are by no means unknown in this country, owing to the assistance afforded for making their acquaintance through the various International Exhibitions, they are nevertheless almost unknown in commerce in consequence of their extreme hardness and the cost of freight in bringing such heavy material so long a distance. Our contemporary thinks that the timbers "will become of much greater value when it is more generally known when to cut and how to season them." We are told that experiments in this direction are being made in order to test their value for various purposes. Several of the best woods are enumerated, and it is said of the "Matai" (*Podocarpus spicata*) that Mr. Buchanan "reports having found a tree of this species prostrate on a piece of land near Dunedin, which from various circumstances was estimated to have been exposed for at least three hundred years in a dense damp bush under conditions most favourable to decay. It was still however sound and fresh."

MAMMEE APPLES (*Mammea americana*) are, we understand, being exported in quantities from the West Indies to New York. The result of the experiment is being watched with some interest.

IN the last number of the *Revue d'Anthropologie* has appeared not only an excellent photograph of the late Dr. Paul Broca, but also a biographical sketch and a complete list of his various contributions to science. His contributions to medical science commence in 1847, and his first anthropological memoir bears date 1850; from these dates to the time of his death this "Bibliographie" is a record of both untiring industry and scientific production, which will be remembered as long as anthropology remains a science.

OUR ASTRONOMICAL COLUMN

THE SOLAR ECLIPSE OF DECEMBER 31.—Although the eclipse of the sun on the last day of the present year will not in any part of these islands amount to six-tenths of the sun's diameter, it is nevertheless as large a one as will be visible until May 28, 1900, and only that on the morning of June 17, 1890, will compare with it in magnitude in the interval. The *Nautical Almanac* furnishes the results of direct calculations for Greenwich, Edinburgh, Dublin, Cambridge, Oxford, and Liverpool. If to the results for the former three observatories we apply the very convenient Littröw-Woolhouse method of distributing the predictions, we shall have the following formulæ for finding Greenwich mean times of first contact, greatest phase and last contact, and the magnitude of the eclipse at any place within or near to the area comprised:—

$$\begin{aligned} \text{First contact} &= 1 \text{ h. } 41'14'' - [9'9891] L + [9'6113] M \\ \text{Greatest phase} &= 2 \text{ h. } 36'32'' - [9'7942] L + [9'3838] M \\ \text{Last contact} &= 3 \text{ h. } 28'63'' - [9'4618] L + [8'7599] M \end{aligned}$$

Where the latitude of the place is put = $50^\circ + L$, and M is the longitude from Greenwich in minutes of time reckoned positive to the east, and negative to the west. Quantities in square brackets are logarithms.

Or the following may be substituted with sufficient accuracy, the factors of L and M being now numbers:—

$$\begin{aligned} \text{First contact} &= 1 \text{ h. } 41'14'' - 0'98 L + 0'41 M \\ \text{Greatest phase} &= 2 \text{ h. } 36'32'' - 0'62 L + 0'24 M \\ \text{Last contact} &= 3 \text{ h. } 28'63'' - 0'29 L + 0'06 M \end{aligned}$$

and the magnitude will be = $0'368 + 0'013 L - 0'002 M$. If we test these formulæ upon Oxford, the latitude of which is $51^\circ 45' 36''$, longitude $5\text{m. } 2'6\text{s. W.}$, we have then $L = +1'76''$, and $M = -5'04\text{m.}$; then for first contact the expression becomes $1\text{h. } 41'14\text{m.} + 1'76 \times -0'98 - 5'04\text{m.} \times 0'41 = 1\text{h. } 41'14\text{m.} - 1'72\text{m.} - 2'07\text{m.} = 1\text{h. } 37'35\text{m.}$ Greenwich mean time, or applying the longitude $-5'04\text{m.} = 1\text{h. } 32'3\text{m.}$ agreeing with the *Nautical Almanac*, and similarly for the other phases. The differences from direct calculations will be within $0'2\text{m.}$, if the place is not too distant.

THE DUNECHT COMET.—There appears to be no doubt now that the comet discovered by Mr. Lohse at Lord Lindsay's Observatory on November 7 is the same as that detected by Mr. Lewis Swift at Rochester, N.Y., on October 11, which had not been previously observed in Europe. The elements, according to the calculations of Mr. S. C. Chandler, jun., of Boston, U.S., and those of Dr. Copeland and Mr. Lohse at Dunecht, have great resemblance to the elements of the third comet of 1869, discovered by M. Tempel, and there seems a probability that he may thus be found to have detected no fewer than four comets of comparatively short period. If the revolution of this comet should prove to be performed in a little less than eleven years it will be found that it must approach very near to the orbit of Mars shortly before the descending node, and, which is of more importance, within $0'4$ of the earth's mean distance, from the orbit of Jupiter in about heliocentric longitude 257° . Mr. Chandler sends us elements calculated from approximate positions on October 21, 25, 28, and in his letter dated November 2 points out their great similarity to those of the Comet 1869 III., and in a circular received from Lord Lindsay we find an orbit computed from Dunecht observations on November 7, 9, and 10; we have thus for comparison:

	Comet of 1880.		Comet of 1869.	
	Chandler.	Copeland and Lohse.	Bruhns.	
T	Nov. 7'714	Nov. 6'6127	Nov. 20'7168	
π	41 41'0	40 24 10	41 17 13	
Node	295 25'4	300 49 41	292 40 29	
i	7 21'7	7 22 13	6 55 0	
Log. q	0'04262	0'043314	0'042416	
Motion.	Direct.	Direct.	Direct.	

Mr. Chandler's T is for meridian of Washington, the other two for that of Greenwich. An ephemeris which he adds proves the identity of Swift's comet with that found by Mr. Lohse.

It may be remarked that, taken as a whole, there is a distant resemblance to the elements of the comet of Biela.

INTRODUCTORY LECTURE TO THE COURSE OF METALLURGY AT THE ROYAL SCHOOL OF MINES¹

THE distinguished metallurgist who has held this lectureship since the foundation of the Royal School of Mines, concluded the introductory lecture he delivered more than a quarter of a century ago² by pointing out to the students who were then beginning their course that "in proportion to the success with which the metallurgic art is practised in this country will the interests of the whole population, directly or indirectly, in no inconsiderable degree be promoted." This is a fact that none of his students are likely to forget.

Looking back on the actual advance of this country during the

¹ By Prof. W. Chandler Roberts, F.R.S., Chemist of the Mint. Condensed by the Author.

² *Records of the School of Mines*, vol. i. pt. 1 (1832) p. 127.

past thirty years, and remembering that the success with which any manufacturing art is practised must bear a direct relation to the way in which it is taught, we cannot but feel how greatly this development of metallurgical knowledge must have been influenced by Dr. Percy's labours. During this period the conditions under which metallurgy is practised have changed considerably; for the field of knowledge has so widely extended, the scale on which operations are conducted is now so great, and the mechanical appliances they involve are so varied and complicated, that while the interest of our subject is deepened its difficulty is gravely increased.

In turning to the history of metallurgy, more especially in its relation to chemical science, it is easy to be led away by the charm of the antiquarian riches of our subject into devoting too much time to this kind of literary research; I may remind you however that much of what is both interesting and full of suggestion, even at the present day, is to be found buried in the treatises by the old writers whose work we inherit and continue.

Primitive metallurgical processes are referred to in some of the oldest known historical records; naturally therefore the development of metallurgy as a science must have been long preceded by its practice as an art, an art for which a place has even been claimed among the religious systems of antiquity.¹ The earlier literature of the subject consists mainly of descriptions of processes; but it is well known that chemistry was to a great extent built up on a metallurgic basis, and Black's singularly advanced definition of chemistry as the "effects produced by heat and mixture"² might well be applied to metallurgy. But of all the phenomena of our subject, probably none have more contributed to advance the science of chemistry than those bearing upon the relations between oxygen and lead; indeed the interest attaching to the mutual behaviour of these two elements is so great that I propose devoting a few minutes to its consideration, more especially as I am anxious to indicate the influence of an ancient process on the scientific views of the present day.

When lead is melted with free access of air, a readily fusible substance forms on its surface. This substance may be allowed to flow away, or if the metal is contained in a suitable porous receptacle, the fusible oxide sinks into this containing vessel; in either case the oxidation of the lead affords a means of separating it from precious or inoxidisable metals if any were originally present in the lead. The above fact has been known from remote antiquity, and the early Jewish writers allude to it as old and well known. They clearly show, for instance, that lead can be removed from silver by being "consumed of the fire," while the silver is not affected. That the Greeks knew and practised the method is abundantly proved, if only by certain specimens of gold and silver now in the adjoining museum, which were recently discovered by Dr. Schliemann. The Arabians investigated the subject; for passing to Geber,³ the greatest of the early chemists (he died in 777), we find a remarkable account of cupellation; he also describes the conversion of lead into a fine powder by calcination with much clearness, and he noticed the fact that after calcination the mass has "acquired a new weight in the operation." I think his subsequent observations on the reduction of altered metals from their "calxes" show that he knew the weight to be increased; in any case it is interesting to remember that his work was in a sense quantitative. He moreover was cognisant of the fact that two different substances may be produced by heating lead in air, and he assumed that "in the fire of calcination a fugitive and inflammable substance is abolished." The alchemists refer continually to the subject, and "deliver themselves," as Roger Bacon said, in his "Speculum Alchimæ," "in the enigmas and riddles with which they clouded and left shadowed to us the most noble science." In the middle of the sixteenth century the truly accomplished metallurgist Biringuccio,⁴ contemporary of Paracelsus and Agricola, seems to have been specially attracted by the phenomenon in question, and he remarks: "If we had not lead we should work in vain for the precious metals, for without its aid we could not extract gold or silver from the stones containing them. . . . The alchemists also," he said, "make use of it in their operations, calcining it by itself or with other substances; but," he goes on to observe, "the calcination, conducted in a reverberatory fur-

nace, is accompanied by a marvellous effect, the result of which should not be passed by in silence; for lead thus treated increases 10 per cent. in weight, and, considering that most things are consumed in the fire, it is remarkable that the weight of lead is increased, and not diminished." Although he subsequently gives evidence of much accurate knowledge of practical metallurgy, his views as to this particular phenomenon were hardly in advance of Geber's; but we may claim Biringuccio as an early metallurgist, who knew the facts, and recognised that they were theoretically important. It was not until nearly a century later (1630) that a French chemist, Jean Rey,¹ stated that the increase in weight came from the air. The problem attracted much attention in England, and it is not a little interesting that among the very first experiments recorded by our own Royal Society is a metallurgical series relating to the weight of lead increased in the fire on the "copels" at the assay office in the Tower, the account being brought in by Lord Brouncker in February, 1661.² [Subsequently, in 1669, John Mayo showed that the increase in weight of calcined metals was due to a "spiritus" from the air.³ Boyle heated lead in a small retort,⁴ and attributed the increase in weight, as Lemery also did,⁵ to his having "arrested and weighed igneous corpuscles."⁶

I need hardly point out how important this calcination of lead was considered by those who defended the Phlogistic theory in regard to chemical change, a theory which, for more than a century, exerted so profound an influence on scientific thought. [As this theory originated with a metallurgist, Becker, it was considered at some length, and it was made evident that the main aim of chemical investigation down to the end of last century was the explanation of calcination, combustion, or oxidation, and that lead was especially useful in solving the problem.]

I might perhaps add that the absorption of oxygen by molten litharge has furnished M. Ste. Claire-Deville,⁷ a physicist and metallurgist, with an important step in the argument as to dissociation, and thus connects the history of the metal with the great advance on the borderland of chemistry and physics in modern times, to which I shall constantly refer.

The above remarks will, I trust, be sufficient to show that conclusions of the utmost importance in the history of chemical theory were based on a very ancient metallurgical process; but I have also selected lead as an illustration, because, in the gradual development of the knowledge derived in the first instance from its metallurgy, there is much that is typical of the mutual relation of theory and practice that still prevails.

When Dr. Percy began his teaching, he considered at some length the kind of assistance that other sciences might be expected to render our subject, considered as a manufacturing art; and this at the time was necessary for two reasons:⁸ first, because he was "able to adduce from his own observation several striking cases in illustration of the advantage of the application of science to practical metallurgy; and, second, because the practice of metallurgy, so far as relates to magnitude of operation, having been developed to an unparalleled extent in this country in the absence of specific public instruction on the subject, it was necessary to justify the providing of such instruction."

The absence of accurate knowledge on the part of those engaged in metallurgy was lamented as long ago as 1700, in an "Inaugural Dissertation of Pyrotechnical Metallurgy," delivered, on March 25 of that year, in the University of Magdeburg; no less a person than the great supporter of the theory of Phlogiston, George Ernest Stahl, presided, and the lecturer was

¹ "Essays de Jean Rey" (reprinted in Paris, 1777), p. 64.

² MS. Register Book of the Royal Society.

³ "Tractatus quinque Medico-Physici," p. 25 et seq. (Oxonii, 1674).

⁴ Collected works, vol. iii. (1744), p. 347.

⁵ "Cours de Chymie" (1675), and English edition (1686), p. 107.

⁶ I am indebted to my friend Prof. Ferguson, M.A., of the University of Glasgow, whose eminence as a historian of chemistry is well known, for several interesting additional facts in connection with the calcination of metals. After referring to Eck (1489), Glauber (1651), and others, he writes: "One of the most curious passages I know is in the 'Hippocrates Chemicus' of Otto Tachen, or Tachenius, a German who lived at Venice and published his book there in 1666. He describes how lead, when burnt to minium, increases in weight. This increase he ascribes to a substance of acid character in the wood used for burning, and then, by a very curious course of argument, based on the saponifying powers of litharge, makes out that lead is of the nature of or contains an alkali, which combines with the 'occult acid of the fat.' This is a curious anticipation of a very modern classification which brings lead into relationship with the alkalies and alkaline earths, as well as of Chevreul's investigations."

⁷ "Leçons sur la Dissociation," 1864.

⁸ Records of the School of Mines, vol. i. pt. 1 (1852), p. 128.

¹ Rössignol, "Les Métaux dans l'Antiquité" (1863).

² "Lectures by Joseph Black, M.D.," vol. i. p. 8 (Edin., 1803).

³ "The Works of Geber," translated by R. Russell (1886), pp. 74, 78, 220, 234.

⁴ "Pyrotechnia" (Vincigra, 1540), translated into French by T. Vincent (Pouen, 1627), p. 41.

Fritschius, who said:—"If in any part of the working of metals there is commonly more owing to experience than reason, truly it is in fusion or melting . . . nevertheless if the reason be asked why the business succeedeth well in this way but in another doth not succeed at all, you have no solid answer, but only that most general one, which is most commonly false, viz. that one fire is stronger and another weaker, and so insufficient." It is just a century since Bishop Watson, Professor of Chemistry and Regius Professor of Divinity in the University of Cambridge, pointed out² that "the improvement of metallurgy and other mechanic arts dependent on chemistry might best be made by public establishment of an Academy, the labours of which should be destined to that particular purpose;" and the School of Mines, thus foreshadowed, was established in 1851, its principal object being to "discipline the students thoroughly in the principles of those sciences upon which the operations of the miner and metallurgist depend."

Our honoured founder, Sir Henry de la Beche, in his Address at the opening of the School of Mines,³ said:—"We still too frequently hear of practical knowledge, as if in a certain sense opposed to a scientific method of accounting for it, and as if experience, without that advantage, was more trustworthy than the like experience with it." Such remarks might, with truth, be made at the present day; but it should nevertheless be remembered that many metallurgical works are successfully conducted in this country by so-called practical men. I do not mean the kind of man so forcibly described by Mr. Bramwell⁴ as one "whose wisdom consists in standing by, seeing, but not investigating the new discoveries which are taking place around him . . . the aim and object of such a man being to ensure that he should never make a mistake by embarking his capital or his time in that which has not been proved by men of large hearts and large intelligence;" nor do I mean the man who accepts no rule but the "rule of thumb"; but I do mean practical men possessing technical knowledge of a high order, whose careful observation enables them to use the results of past experience in dealing with circumstances and conditions analogous to those they have met with before, and with which long practice has made them familiar. It would be difficult to overrate the value and importance of such knowledge as theirs, and, when we remember the scale on which smelting and other operations are carried on, it will be obvious that this kind of knowledge can only be gained in the works, and not in the laboratory or lecture-room; for, however careful the metallurgical teaching here may be, it can only be practical in a limited sense. At the same time it must be borne in mind that a man trained to scientific methods starts with the enormous advantage of being able to deal with circumstances and conditions that are new to him, and with which therefore he cannot be said to be "familiar." The technical skill that time and opportunity can alone give him will then rest on a solid basis. I repeat, however, that I am anxious at the outset to guard against undervaluing the teaching of experience unaided by reasoning that we should recognise as scientific; for it is only necessary to witness such operations as the roasting of a large mass of ore on the bed of a furnace, or the forging of many tons of iron under a steam hammer, to appreciate the value of the subtle skill of sight and touch on which success depends.

I have thus ventured to trace the relation between scientific and technical men, as hitherto there have been misunderstandings on both sides, or, as Dr. Williamson so well observes:⁵—"Men of detail do not sufficiently appreciate the value and usefulness of ideas, or of general principles; and men of science, who learn to understand and control things more and more by the aid of the laws of nature, are apt to expect that all improvements will result from the development and extension of their scientific methods of research, and not to do justice to the empirical considerations of practical expediency, which are so essential to the realisation of industrial success in the imperfect state of our scientific knowledge."

While it is no longer necessary to justify the scientific teaching of metallurgy, as Dr. Percy did, it is as important as ever that the true relation of Theory and Practice should be clearly understood. It rarely happens that a process can be transferred from the laboratory to the works without important modifications;

and we must remember that metallurgy is a manufacturing art, and that, when the truth of a theory has been demonstrated, a dividend has to be earned; this would indeed often be difficult without the aid of the technical man. Practical men have, however, ceased to undervalue science; and the most practical body of men in the world, in the best sense of the term, the ironmasters of this country, on whom its prosperity so largely depends, formed themselves ten years ago into an Iron and Steel Institute, many of the members of which possess high scientific attainments and are distinguished for scientific research.

Let us turn, then, to the advice given us by those who are accustomed to deal with metals on a large scale. Mr. I. Lowthian Bell stated in his address as president of the Institute in 1873¹:—"If we would avoid the failure of what may be designated unscientific practice, or the failure of impracticable science, we must seek to combine commercial intelligence with a knowledge of those natural laws which form the only trustworthy groundwork of the complicated processes in which we are engaged."

Dr. Siemens² said in 1877:—"It is not many years since practical knowledge was regarded as the one thing requisite in an iron-smelter, whilst theoretical knowledge of the chemical and mechanical principles involved in the operations was viewed with considerable suspicion;" and he adds, with reference to the teaching of the School of Mines and of a general Technical University:—"But it must not be supposed that I would advocate any attempt at comprising in its curriculum a practical working of the processes which the student would have to direct in after-life. . . . Let technical schools confine themselves to teaching those natural sciences which bear upon practice, but let practice itself be taught in the workshop and in the metallurgical establishment."

The president for 1879, Mr. E. Williams, a most eminently practical man, and one of the founders of the prosperity of the great Cleveland iron district, urged³ "educated intellectual young men, who now hang listlessly about the professions . . . to break through the absurd old prejudice against seemingly rough work," in order that they may act as scientifically trained managers.

I have thus appealed to authorities, because my own practical work has been mainly confined to a limited branch of metallurgy. I say limited, for although, on looking into the matter, I find, to my surprise, that I have during the last ten years been responsible for the fineness of 330 tons of gold and 740 tons of silver, this, though of a total value of forty-seven millions sterling, is a comparatively small bulk of metal, and the operations through which it passes are seldom complicated; but I am none the less convinced that in metallurgical works generally, as in a mint, the work can only be efficiently conducted by taking advantage to the utmost extent of the aid that science has to offer, a mint only differing from other works by the extraordinary care and vigilance which must be exercised to insure accuracy and avoid loss in dealing with the precious metals. Even this difference is less marked than formerly, and as attention to minute details is becoming more and more essential to the profitable conduct of works, my experience in this respect will be useful to you.

As regards the actual training in the school, I believe that our utmost efforts should be devoted to giving the students a thorough acquaintance with scientific methods and metallurgical principles, furnishing them at the same time with as many well-ascertained facts as possible. Here I may perhaps be permitted to quote a few words from Prof. Huxley's⁴ recent address at Birmingham, as they bear so directly on our subject; he said, "What people call applied science is nothing but the application of pure science to particular classes of problems. It consists of deductions from those general principles, established by reasoning and observation, which constitute pure science. No one can safely make these deductions until he has a firm grasp of the principles; and he can obtain that grasp only by personal experience of the processes of observation and of reasoning on which they are founded."

In one important branch of metallurgy—assaying—the teaching in the School is thoroughly practical, and the operations you may in future be called upon to conduct will not differ from those taught in this laboratory. The teaching will, I am glad to say, be now specially entrusted to my friend Mr. Smith, the value of whose instruction in my own case I gratefully acknowledge.

¹ *Journal of the Iron and Steel Institute* (1873), No. 1, p. 12.

² *Ibid.* (1877), No. 1, p. 7.

³ *Ibid.* (1879), No. 1, p. 24.

⁴ *NATURE*, vol. xxii. p. 548.

¹ "Pyrotechnical Metallurgy," by J. C. Fritschius of Schwartzburg (translated in 1704), p. 203.

² "Chemical Essays," 2nd edition (1732), vol. i. p. 47.

³ *Records of the School of Mines*, vol. i. pt. 1 (1852), p. 20.

⁴ British Association Report, Brighton (1872), p. 238.

⁵ "A Plea for Pure Science" (Inaugural Lecture, University College, London, 1870).

It can hardly be questioned that until the School of Mines was established the metallurgical success and reputation of this country rested to a remarkable extent on the exceptional skill of its technical men. I think therefore we may fairly be asked to consider whether the metallurgical teaching of the School has been justified, and how far advance has been due to trained scientific thought.

Of all the metallurgical operations conducted in this country, those connected with iron are, of course, the most important. The production of pig-iron alone in the United Kingdom has increased from two million seven hundred thousand tons in 1852 to six million two hundred thousand tons last year, a maximum slightly in excess of this figure having been reached in the year 1872. Now the Bessemer process, the first patent in connection with which was taken out in 1855, has reduced the cost of steel from 50% to 6% per ton, and has changed the whole aspect of the iron and steel manufacture; indeed, the success with which this process alone is conducted may almost be regarded as an index of our national prosperity. Notwithstanding the almost universal depression of trade during the last few years, the output of steel has been steadily increasing; and it is estimated that in 1879 this country produced nearly a million tons in the Bessemer converter, double the entire produce of the remainder of the world in the year 1870 by the same process.¹ The output of Bessemer steel in America has, however, advanced with still more rapid strides; for last year she actually produced, with far fewer converters, ninety-four thousand tons more than this country. It will be evident, therefore, that every improvement effected in this process is of truly national importance, and I would briefly refer to the greatest that has been introduced in recent years.

In 1855 the fact was established that pig-iron from the blast-furnace contains the greater part of the phosphorus originally present in the ore. Dr. Percy pointed out that phosphorus is not eliminated in a sensible degree in the Bessemer process, as it is in the old process of puddling; and he stated that if the Bessemer process is to be "generally applicable in this country, it must be supplemented by the discovery of a process of producing pig-iron sensibly free from sulphur and phosphorus, with the fuel and ores which are now so extensively employed in our blast-furnaces."² The problem, so far as it relates to the elimination of phosphorus, has received the attention of many of the first metallurgists in this and other countries;³ but the practical application of basic linings in the Bessemer converter is the outcome of Dr. Percy's teaching; for Mr. S. G. Thomas was a student of the School of Mines, and his partner, Mr. Gilchrist, is an Associate. Mr. Snelus is also an Associate, and Mr. Riley long worked in the metallurgical laboratory. The process not only gives hope that it will be possible to utilise the large quantities of ore in the well-known Cleveland district, but is also widely practised with success on the Continent.⁴ It is probable therefore that the large deposits of ore in the basin of the Saar, and those of Lorraine and Luxembourg, which in extent are equal to the Cleveland district, while containing a much greater amount of phosphorus, will now be available. During a recent visit to the Hoerde Works in Westphalia, where I witnessed the operation, Herr Massenez, the director, told me that 10,000 tons of "Thomas-Gilchrist" metal have already been produced there since the adoption of the process a few months ago. . . .

I had intended to indicate the metallurgical work done by the more prominent men who have been associated with the school, but I found that it would not be possible, in the brief time at my disposal, to do justice to such as Bauerman, Dick, Gibb, Hackney, Matthey, Pearce, Riley, Willis, and others, whose labours have placed them so high in the ranks of English metallurgists. You will, however, as the course proceeds, have opportunity of becoming familiar with their names.

In referring to the past teaching of the school I must remind you of the importance of rigorous and minute inorganic analysis; and it is the more necessary that I should do so from the fact that the peculiar charm of organic research appears, as has been pointed out by Prof. Abel,⁵ to lead the younger chemists to "under-estimate the value and importance, in reference to the advancement of science, of the labours of the plodding investi-

gator of analysis." I am satisfied, however, that, if we bear the traditions of the chemical and metallurgical laboratories of the School of Mines in view, we are not likely to under-rate the importance of analytical work; and much conclusive evidence as to the value of the teaching of the past thirty years is afforded by the labours of the accomplished analysts who have from time to time worked under Dr. Percy's direction.

The direct influence of the School on the success with which metallurgy has been practised in this country has been most marked, and would alone afford an answer to the question whether the possession of high scientific attainments is generally advantageous to the successful conduct of metallurgical works. It must not be forgotten that our subject is constantly receiving valuable aid from branches of science other than chemistry; and this can hardly be better shown than by the growing importance of physical research in connection with metallurgical problems. I would incidentally remind you that it is the more important for us to consider this, because special attention was directed to the question in the evidence given before the Royal Commission on Scientific Instruction,⁶ whose recommendations will, it is to be hoped, extend the influence of the School of Mines.

In connection with this branch of our subject a most prominent position must be given to the production of high temperatures, as it will be obvious that we have principally to consider the reactions of the elements when under the influence of heat. In the first half of the present century temperatures higher than the melting point of zinc were not known with any degree of certainty; but in 1856⁷ M. Henri Ste. Claire-Deville pointed out that chemistry at high temperatures, that is to say, up to the blue-white heat at which platinum volatilises and silica fuses, remained to be studied. Since then, in conjunction with M. Troost, he has given us certain fixed points, such for instance as the boiling points of cadmium and zinc; and Deville's researches on dissociation have entirely modified the views generally entertained in regard to the theory of combustion. Indeed we owe so much to this illustrious teacher, that the best homage we can offer him will be to work in the directions he has indicated. M. Stas has proved that it is perfectly easy to distil even large quantities of silver from one lime crucible to another,⁸ a fact which has been taken advantage of by Mr. Lockyer and myself in some experiments on the absorption-spectra of the vapours of certain metals at high temperatures.⁹

As regards scientific advance of a more essentially practical character, the gradual discovery of the fact that in certain cases fuel can be best employed if it be previously converted into gas, and the recognition of the advantages to be derived from a preliminary heating of the gases and the air, has led to the wide adoption of the regenerative system, by which the waste heat of the furnace is utilised for heating the incoming air or combustible mixture of air and gas necessary to effect the required operation. Dr. Siemens has thus shown us how to economise fuel to a vast extent, it being now possible to produce a ton of steel by the use of 12 cwt. of small coal instead of three tons of coke required to melt it in the old form of furnace. By the command of high temperatures, moreover, he has developed new processes in the metallurgy of iron, which are resulting in the replacement of the old "cinder-mixed" wrought iron by "cinder-free" ingot iron and steel.¹⁰ The degree of heat attainable by the regenerative furnace is, however, limited to the temperature of dissociation of carbonic acid and aqueous vapour, so that the temperature never can exceed about 2600° C.; but during the present year¹¹ Dr. Siemens has employed the far greater heat of the electric arc for the fusion of steel and platinum.¹² Bearing in mind the interest excited by recent experiments on the effect of intense heat on bodies now considered to be elementary, we may expect physicists to look to us for aid in developing the methods of employing high temperatures.

The essential difference in the properties of certain alloys produced by a small difference of composition brings me to one very distinctive feature of metallurgy, the enormous influence

¹ Report, vol. ii. Minutes of Evidence, p. 86 (1874).

² *Ann. Chim. et Phys.* [3], t. xlii. p. 182; *Comptes rendus*, t. xc. (1880), p. 773.

³ "Sur les Lois des Proportions chimiques" (1865), p. 37.

⁴ *Proc. Roy. Soc.* vol. xlii. (1875), p. 344.

⁵ Akerman, *Journal of the Iron and Steel Institute*, No. 2 (1878), p. 360.

⁶ *Engineering*, vol. xxix. (1880), p. 478.

⁷ Figures convey but little impression as to such high temperatures; but it may be mentioned that Dewar has given 7000° C. as approximately the temperature of the electric arc (*Brit. Assoc. Rep.* 1873, p. 466), and, according to Rossetti, the true temperature of the sun can hardly be less than 10,000° C. or more than 20,000° C.—*Phil. Mag.* [5], vol. viii. p. 550 (1879).

¹ *Times*, December 31, 1879.

² "Metallurgy—Iron and Steel" (1864), p. 819.

³ M. Gruner, *Annales des Mines* (1869), t. xvi. p. 199.

⁴ M. Gruner, *Annales des Mines*, part 1 (1879), p. 146; H. von Tunner, *Zeitschrift der berg- und hüttenmännischen Vereins für Steyermark u. Kärnten*, xii. Jahrg., Mai-Juni 1880; Herr J. Massenez, *Engineering*, vol. xxx. (1880), p. 198.

⁵ British Association Report, Plymouth (1877), p. 44.

exerted on a large mass of metal by a trace of another metal or metalloid—that is, by a quantity so small that it appears to be out of all proportion to the mass in which it is distributed.

I think it may safely be asserted that in no other branch of applied science has the operator to deal with quantities that are at once so vast and so minute; and the course will not have proceeded far before you will recognise this fact.

It may be that the trace to be extracted is alone of value—as, for instance, the few grains of gold that can be profitably extracted from each ton of a material, which, though containing only one part of gold in five millions by volume, is thereby entitled to be regarded as an auriferous deposit that can be profitably worked; or it may be the minute percentage of a metalloid which must be extracted in order that the physical properties of a large mass of metal may not be entirely altered.

[Numerous instances of the influence of small traces of metals and metalloids, including the following, were then given:—]

In 1866 Graham showed,¹ by experiments with which I had the privilege of being connected, that the presence of occluded gases in metals often exerts a marked influence on their molecular structure. In the case of iron he urged that metallurgists should study the effects of occluded gases, more especially carbonic oxide, the weight of which, according to his experiments, could not exceed the $\frac{1}{10}$ per cent. of the weight of iron in which it was present. The significance of such facts is now under consideration by a Committee of the Institution of Mechanical Engineers,² and the question of the presence of gas in steel, either occluded or retained in the form of bubbles, is further being investigated by Chernoff,³ Müller,⁴ and others.

M. Nyst, of the Brussels Mint, has lately found that the presence of $\frac{1}{10}$ per cent. of silicon in standard gold will so affect its molecular grouping as to render it possible for a thin strip to bend by its own weight, as zinc would, in the flame of a candle.

The growing importance of physical research in connection with metallurgy is shown by the fact that physical methods are now constantly appealed to by those interested in metallurgy, more especially in the case of iron and steel. We are told, for instance, that the hardness of steel may be correctly inferred from a numerical determination of its coercive force;⁵ it is sought to establish the actual nature of the change in the mode of existence of the carbon in steel that accompanies hardening by determining its thermo-electric properties;⁶ and the hope is held out⁷ to us that the time will soon come when boiler-makers will electrically test their plates, possibly by the aid of the induction-balance, just as they now test them for ductility and tenacity. I can only add the expression of a belief that this powerful weapon of molecular research which Prof. Hughes has given us will yield good results in the hands of some of you.

The results of mechanical tests are also of the highest importance. Not long since the appearance of the fracture of a sample of metal was considered to afford trustworthy and sufficient evidence as to its nature and properties; but such rough methods have given place, in the hands of Kirkaldy and others, to the rigorous physical and mechanical investigation to which metals must now be submitted as a matter of ordinary routine. The results, tabulated or plotted into curves, which mark the influence of each constituent or impurity, form permanent records of the greatest value.⁸

It has only been possible for me to indicate the more important conditions affecting the successful practice of metallurgy. I have traced the relation between technical and scientific workers; but there is yet another condition of somewhat recent growth. The enormous scale on which operations are now conducted renders it more necessary than formerly for those engaged in metallurgical enterprise to seek the aid of capitalists. The result is that a large share in the control of many important works falls to the non-scientific members of the Board of Directors, men of high commercial ability, but whose knowledge of the importance of scientific work is necessarily limited. It is true that

they may recognise the necessity for scientific aid in the works with which they are connected, but they are too often unconscious of the labour and difficulty that are involved in the attainment of accurate scientific knowledge. I am convinced, however, that facts are gradually compelling them to recognise that the value of a metal may entirely depend on whether it does or does not contain a trace of impurity, and that the exact method of treatment to be adopted depends much on the character of the materials employed; they will therefore examine more carefully than they have hitherto done the qualifications of men to whom important duties are entrusted, and will insist that the services of only adequately trained metallurgists shall be secured.

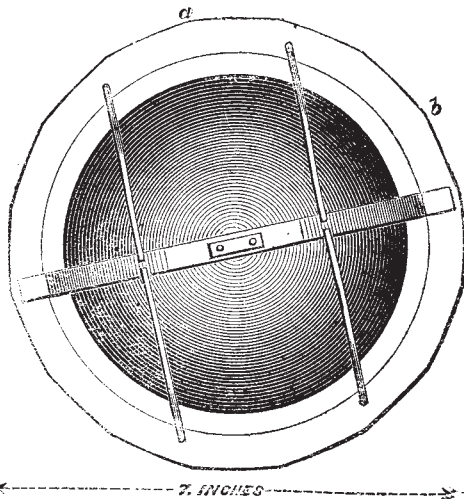
I shall have to direct your attention to the minute care with which details affecting commercial interests are now investigated;¹ and your success will further depend on the facility with which you are able to use the “tools of thought” furnished by chemistry, physics, and mechanics. Whether you will ever possess the tact and judgment necessary to direct such works as Dowlais with an army of 10,000 people, obviously depends on personal qualifications which I can but little influence.

I venture to hope that you will, by original research, add to the general advance of science, for, as the late Prof. Clifford has reminded us, what have often proved to be the most useful parts of science have been investigated for the sake of truth, and not for their usefulness.

Dr. Percy found metallurgy practised in this country mainly as an empirical art. He may well feel, to borrow the words of an old writer, that in his hands “the business of metallurgy and essaying has not only been illustrated but also improv’d, amended, and enrich’d”; for his works contain a record of its progress, his teaching and researches have secured it a scientific basis, and he has trained a body of scientific workers, in whose hands the immediate future of metallurgy to a great extent rests. Bearing in mind how much the progress of our science means to England, I cannot but be conscious that, in attempting to continue this work, I undertake a grave responsibility.

ON AN EXPERIMENTAL ILLUSTRATION OF MINIMUM ENERGY²

THIS illustration consists of a liquid gyrost at of exactly the same construction as that described and represented by the annexed drawing, repeated from NATURE, February 1, 1877, p. 297, 298, with the difference that the figure of the shell is prolate instead of oblate. The experiment was in fact conducted with the actual apparatus which was exhibited to the British Association at Glasgow in 1876, altered by the substitution of a



shell having its equatorial diameter about $\frac{9}{10}$ of its axial diameter, for the shell with axial diameter $\frac{9}{10}$ of equatorial diameter which was used when the apparatus was shown as a successful gyrost.

¹ In illustration of this see an exhaustive mathematical paper on the values of iron ores, by Prof. A. Habets: *Cuyper's Revue Universelle des Mines* (1877), t. i. p. 504.

² By Sir William Thomson, F.R.S. British Association, Swansea, Section A.

¹ *Phil. Trans.* 1866, p. 438.

² First Report of the Committee on the Hardening, Tempering, and Annealing of Steel, 1879.

³ "On the Structure of Cast Steel Ingots." Translated for the Institution of Mechanical Engineers by W. Anderson, C.E. (1879).

⁴ *Berichte der deutschen chemischen Gesellschaft*, 1879, No. xii. 93; *Glaser's Annalen für Gewerbe und Bauwesen*, August, 1880, p. 138.

⁵ Tréve and Durassier, *Comp. rend.*, t. lxxx. (1875), p. 799; Wattenhofen, *Journal of the Iron and Steel Institute*, 1879, No. 1, p. 305.

⁶ Barus, *Phil. Mag.* [5], vol. viii. p. 347.

⁷ W. H. Johnson, *Chemical News*, vol. xlii. (1880), p. 70.

⁸ V. Deshayes, "Classement et Emploi des Aciers" (Paris, 1880); also *Bull. Chem. Soc.* tom. xxxi. (1879), p. 166.